

Attorney Docket No.: 84480  
Customer No. 23523

A FIBER OPTIC SWITCH EMPLOYING OPTICAL AMPLIFIERS

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT ANTHONY A. RUFFA, citizen of the United States of America, employee of the United States Government, a resident of Hope Valley, County of Washington, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification.

JEAN-PAUL A. NASSER, ESQ.  
Reg. No. 53372  
Naval Undersea Warfare Center  
Division Newport  
Newport, RI 02841-1708  
TEL: 401-832-4736  
FAX: 401-832-1231

1 Attorney Docket No.: 84480

2

3 . A FIBER OPTIC SWITCH EMPLOYING OPTICAL AMPLIFIERS

4

5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used  
7 by or for the Government of the United States of America for  
8 governmental purposes without the payment of any royalties  
9 thereon or therefore.

10

11 CROSS REFERENCE TO OTHER PATENT APPLICATIONS

12 This patent application is co-pending with a related patent  
13 application also entitled A FIBER OPTIC SWITCH, (Attorney Docket  
14 No. 82680), by Anthony A. Ruffa the named inventor of this  
15 application.

16

17 BACKGROUND OF THE PRESENT INVENTION

18 (1) Field of the Invention

19 The present invention relates to a method for switching a  
20 digital signal in an optical fiber from an input fiber to a  
21 plurality of output fibers and an apparatus for performing such  
22 switching. More specifically, the present invention relates to  
23 a method for switching a digital signal in an optical fiber from  
24 an input fiber to a plurality of output fibers by means of at

1 least one laser-activated amplifier and a plurality of optical  
2 attenuators without requiring a conversion from an optical  
3 signal into an electrical signal and at high switching speeds.

4 (2) Description of the Prior Art

5 There exist numerous methodologies whereby optical signals  
6 may be switched from one fiber to another without first  
7 converting to an electronic signal and then back to an optical  
8 signal. Most of these methods involve some change in the medium  
9 to bend the light beam and achieve a physical switching of the  
10 input beam into two or more output beams. Some of the methods  
11 used include micro-electro-mechanical systems (MEMS), liquid  
12 crystals, tiny ink-jet bubbles, thermo-optical switches, tunable  
13 lasers, or using sound waves. As a result of requiring a change  
14 in the propagating medium to achieve switching, most of these  
15 switching methods have relatively slow switching speeds, e.g.,  
16 on the order of 100 Hz. There are methods for switching light  
17 with light without changing the medium. These methods typically  
18 rely on nonlinearities. The problem with a nonlinear system is  
19 that it does not work well for switching broadband signals,  
20 which can be viewed as sums of narrowband signals. The sum of  
21 many narrowband signals will have a different response than the  
22 response of a single narrowband signal.

23 What is needed is a methodology for switching an optical  
24 input signal into a plurality of optical outputs that does not

1 depend upon nonlinearities or upon the implementation of a  
2 change in medium giving rise to unacceptably slow switching  
3 speeds.

## SUMMARY OF THE INVENTION

5 Accordingly, it is an object of the present invention to  
6 provide a method for switching an optical signal in a fiber  
7 optic assembly.

8 It is a further object of the present invention to provide  
9 a fiber optic switch for switching an optical signal in a fiber  
10 optic assembly.

11        The method disclosed herein is for use with a fiber optic  
12 system where the signals have one of two discrete power levels,  
13 one level representing "0" and the other representing "1". The  
14 method involves directing a digital input signal into an input  
15 optical fiber and then splitting the input signal into multiple  
16 input signals by splitting the input optical fiber to form a  
17 plurality of output optical fibers. Each output optical fiber  
18 carries a single one of the split input signals. This method  
19 further involves selectively amplifying one or more of the split  
20 input signals with a laser-activated amplifier. The  
21 amplification of the one or more split input signals is such  
22 that the power levels are much higher than the levels for the  
23 "0" and "1" states. Finally, all of the signals in the output  
24 optical fibers are attenuated.

1        In accordance with the present invention a fiber optic  
2 switch comprises an input optical fiber. An input signal is  
3 provided to the input optical fiber. At least one splitter is  
4 used to split the input signal and the input optical fiber to  
5 form a plurality of optical fibers and a plurality of split  
6 input signals. Each of the optical fibers carries a single  
7 split input signal. At least one laser activated amplifier  
8 controllably amplifies one of the split input signals and a  
9 plurality of attenuators attenuates the plurality of the split  
10 input signals to produce at least one output signal.

11

12                    BRIEF DESCRIPTION OF THE DRAWINGS

13        These and other features and advantages of the present  
14 invention will be better understood in view of the following  
15 description of the invention taken together with the drawings  
16 wherein:

17        FIG. 1 provides a diagram of a fiber optic switch of the  
18 present invention;

19        FIG. 2 provides a diagram of a fiber optic switch of the  
20 present invention illustrating multiple levels of binary  
21 switches; and

22        FIG. 3 provides a diagram of a configuration of the fiber  
23 optic switch of the present invention illustrating the extension  
24 to  $n$  output fibers.

1                   DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

2       The optical switch of the present invention switches a  
3       digital signal from an input optical fiber to one or more output  
4       optical fibers. The embodiments of the present invention,  
5       discussed more fully below, function in a fiber optic system  
6       using two discrete power states for "0" and "1". Switching is  
7       achieved by splitting an optical input signal into a plurality  
8       of signals, selectively amplifying certain of the split signals  
9       through a controller, and then attenuating all of the split  
10      signals to provide at least one output signal corresponding to  
11      the optical input signal.

12      With reference to FIG. 1, there is illustrated an  
13      embodiment of an optical switch of the present invention. The  
14      incoming signal to be switched is contained by fiber 1. The  
15      signal is split into two fibers 3, 3' with a splitter 2.  
16      Splitter 2 is a device well known in the art that divides a  
17      single incoming optical signal into at least two separate output  
18      signals such that each output signal corresponds to the incoming  
19      signal but is scaled to a lower intensity by division of the  
20      signal power.

21      Fibers 3, 3' each have an attached amplifier 5, 5'. Each  
22      amplifier 5, 5' amplifies the incoming signal in its respective  
23      fiber 3, 3' when a pumping laser (not shown) within the  
24      amplifier is turned on. As known in the art, these amplifiers

1 can be constructed from doped fiber optic segments. The pumping  
2 laser can be electrically controlled or optically controlled by  
3 control 8. As a result of passing through amplifier 5, 5', each  
4 signal is amplified. Finally, each of the fibers in 3 and 3'  
5 pass through an attenuator 7, 7' that attenuates the signal by  
6 an amount identical to the amount amplified by the amplifier.

7 Therefore, in order to switch the signal from fiber 1 to  
8 fiber 3, controller 8 would deliver a control signal to  
9 amplifier 5 activating its pumping laser to amplify the received  
10 signal. Conversely, if the signal is to be switched from fiber  
11 1 to fiber 3', controller 8 would cause amplifier 5' to be  
12 powered by its laser. In addition, controller 8 can switch the  
13 signal to both fibers 3, 3' by powering pumping lasers in both  
14 amplifiers 5, 5'.

15 In a fiber optic system having two discrete power states a  
16 "0" state may correspond to an optical power range between 0 and  
17 1 mW, and a "1" state may correspond to a 3 to 4 mW range. In  
18 such a system, the digital signal in fiber 3 and 3' is amplified  
19 in amplifier 5 or 5' by a factor of 10 so that the "0" power  
20 range is increased to 0 to 10 mW and the "1" is increased to 30  
21 to 40 mW. After amplification, the signals in both output  
22 fibers 3, 3' are attenuated by attenuators 7 and 7' by a factor  
23 of 10. In an example where the signal was amplified in fiber 3  
24 but not fiber 3', then the attenuator 7' reduces the maximum

1 power in the unamplified fiber 3', to 0.4 mW, well below the  
2 maximum threshold recognized as a "0". The signal will not be  
3 recognized in the unamplified output fiber 3', but it will be  
4 recognized in the amplified output fiber 3 because it was  
5 attenuated by the same amount as it was amplified. If the  
6 magnitude of amplification is equal to the original signal to  
7 noise ratio, then the signal to noise ratio for the signal in  
8 output fiber 3 will be approximately that of the signal in input  
9 fiber 1.

10 There are several optical amplifiers known in the art that  
11 could be used in the present invention. The most common optical  
12 amplifier that could be used is the erbium doped optical fiber  
13 amplifier, which operates at wavelengths from 1530 to 1610 nm,  
14 and encompasses the 1550 nm band used for fiber optic  
15 transmission (where the fiber is most transparent). Another  
16 common amplifier is the semiconductor optical amplifier. Other  
17 optical amplifiers having different wavelengths and modes of  
18 operation can be used within the scope of this invention. The  
19 response time for erbium doped optical fiber amplifier devices  
20 is currently in the microsecond range. The response time for  
21 semiconductor optical amplifier devices is in the nanosecond  
22 range. The switching speed of the present invention would  
23 therefore be dependant on the type of amplifying device used in  
24 the invention. It would, however, be of a considerably higher

1 speed than a physical switching device that relies upon a change  
2 in medium.

3 In any of the embodiments of the present invention, the  
4 attenuators can be either a filter or partially opaque section  
5 of fiber. In the preferred embodiment of the invention, the  
6 amount of signal attenuation will equal the amount of signal  
7 amplification, and the amount of signal amplification ideally  
8 will be equal to or greater than the signal to noise ratio.

9 It is well known in the art that optical amplifiers  
10 decrease the output signal to noise ratio. The ratio of signal  
11 to noise ratio of the input signal to that of the output signal  
12 can be 5 to 10 dB, depending upon the amplifying device. In the  
13 present invention this does not present a problem, because there  
14 are only two power states in the optical fiber system. The  
15 signal to noise ratio requirements for a two state system are  
16 low. Therefore, other than a reduction in signal to noise ratio  
17 due to amplification, the signal to noise ratio of the signal in  
18 the input fiber 1 is otherwise preserved as it is ultimately  
19 amplified and attenuated to achieve switching the signal to a  
20 separate output fiber. Amplifying the digital signal first and  
21 then attenuating it maintains the ratio of signal power to  
22 optical noise floor power.

23 The method and apparatus as described can be cascaded to  
24 switch an incoming signal to any desired number of optical

1 fibers. FIG. 2 illustrates an incoming signal 1 that can be  
2 switched to any of four fibers 9, 9', 9'', 9''' through the use  
3 of two levels of binary switches. As before, control 8 controls  
4 amplification at each amplifier 5, 5', 5'', and 5'''. Note that  
5 it is not in general necessary to amplify the signal and  
6 attenuate it at each switch. Rather, amplifiers 5, 5', 5'',  
7 5''' and attenuators 7, 7', 7'', 7''' are located only at the  
8 terminus output fibers 9, 9', 9'', 9''''. Similarly, the signal  
9 from an incoming fiber can be diverted optically to any of  $2^n$   
10 fibers by increasing the number of levels of binary switches.

11 FIG. 3 is a generalized embodiment of the present invention  
12 in which the signal in input fiber 1 is diverted into n output  
13 fibers. One or more splitters 2 create the desired number of  
14 outputs. In such an embodiment, each output fiber typically  
15 contains an amplifier 5 and an attenuator 7 as illustrated in  
16 FIG. 1.

17 The fiber optic switch disclosed can be generalized for an  
18 arbitrary broadband signal, so that such a signal can be  
19 optically switched from an input fiber to a plurality of output  
20 fibers. Each frequency will be equally amplified and  
21 attenuated. The only requirement is that there are only two  
22 discrete allowable states for each narrowband frequency  
23 component.

1        It is to be understood that the invention is not limited to  
2        the illustrations described and shown herein, which are deemed  
3        to be merely illustrative of the best modes of carrying out the  
4        invention, and which are susceptible of modification of form,  
5        size, arrangement of parts and details of operation. The  
6        invention rather is intended to encompass all such modifications  
7        that are within its spirit and scope as defined by the claims.